

CLAIMS

1. A wireless communications system for transmitting/receiving a first wireless signal from a first wireless communications device and a second wireless signal from a second wireless communications device, the first and second wireless signals having different frequency bands from each other, wherein:

the first wireless communications device includes:

10 a first frequency converter for downconverting the second wireless signal transmitted from the second wireless communications device to a first low-frequency signal;

a first sampler for oversampling the first low-frequency signal downconverted by the first frequency converter; and

15 a first demodulation digital circuit for demodulating the signal oversampled by the first sampler;

the signal demodulated by the first demodulation digital circuit has a center frequency of f_1 [Hz];

the second wireless communications device includes:

20 a second frequency converter for downconverting the first wireless signal transmitted from the first wireless communications device to a second low-frequency signal whose center frequency f_d [Hz] is equal to a difference between a center frequency of the first wireless signal and that of the second wireless signal;

25 a second sampler for undersampling the second

low-frequency signal downconverted by the second frequency converter; and

a second demodulation digital circuit for demodulating the signal undersampled by the second sampler;

5 a sampling frequency used in the first sampler and that used in the second sampler are the same sampling frequency f_s [Hz];

the sampling frequency f_s [Hz] is set to a value that is an even-number multiple of a wireless symbol transmission rate such that oversampling is done in the first sampler and
10 undersampling is done in the second sampler; and

the center frequency f_i [Hz] is $1/2$ to 1 times a frequency corresponding to a bandwidth of the first and second wireless signals and is $1/2^N$ (N is a natural number) times the sampling frequency f_s [Hz].

15

2. The wireless communications system according to claim 1, wherein where the bandwidth of the first and second wireless signals is $2 \times B_{ch}$ [Hz] and the wireless symbol transmission rate is f_{sym} [Hz], the sampling frequency f_s [Hz] and the center frequency f_i [Hz] are expressed as shown in the following expressions:
20

$$f_i = \frac{2k f_{sym}}{2^N}$$

$$f_s = 2^N f_i$$

where k is an integer satisfying

$$\frac{fd+Bch}{(n+1)fsym} \leq k \leq \frac{fd-Bch}{nfsym} \quad \dots \text{Exp. 12}$$

and

$$k \leq \frac{fd}{2fsym} \quad \dots \text{Exp. 14}$$

and N is an integer satisfying

$$\log_2 \left\{ \frac{fd+Bch}{(n+1)Bch} \right\} \leq N \leq \log_2 \left\{ \frac{2(fd-Bch)}{nBch} \right\} \quad \dots \text{Exp. 22}$$

where n is an integer satisfying

$$1 \leq n \leq \frac{fd-Bch}{2Bch} \quad \dots \text{Exp. 7}$$

3. The wireless communications system according to claim 1,
 10 wherein:

the first frequency converter downconverts the second wireless signal transmitted from the second wireless communications device to a first low-frequency signal whose center frequency is f_j [Hz]; and

15 the first low-frequency signal is demodulated by the first demodulation digital circuit after being corrected to a signal whose center frequency is f_i [Hz] at a position preceding or following the first sampler.

20 4. The wireless communications system according to claim 1, wherein:

the center frequency f_d is 40.000 [MHz]; and
the frequency f_i and the sampling frequency f_s are
 $f_i=3.072$ [MHz] and $f_s=24.576$ [MHz],
 $f_i=3.072$ [MHz] and $f_s=12.288$ [MHz],
5 $f_i=4.608$ [MHz] and $f_s=36.864$ [MHz],
 $f_i=4.096$ [MHz] and $f_s=32.768$ [MHz], or
 $f_i=3.584$ [MHz] and $f_s=28.672$ [MHz].

5. The wireless communications system according to claim 1,
10 wherein:

the first demodulation digital circuit includes:

a first quadrature demodulator for
quadrature-demodulating the signal oversampled by the first
sampler;

15 a first low-pass filter for low-pass-filtering the signal
quadrature-demodulated by the first quadrature demodulator; and

a first received data reproducing section for reproducing
received data from the signal low-pass-filtered by the first
low-pass filter;

20 the second demodulation digital circuit includes:

a second quadrature demodulator for
quadrature-demodulating the signal undersampled by the second
sampler;

a second low-pass filter for low-pass-filtering the
25 signal quadrature-demodulated by the second quadrature

demodulator; and

a second received data reproducing section for reproducing received data from the signal low-pass-filtered by the second low-pass filter;

5 the first quadrature demodulator converts the signal oversampled by the first sampler to a signal including a component whose center frequency is zero; and

the second quadrature demodulator converts the signal undersampled by the second sampler to a signal including a component
10 whose center frequency is zero.

6. The wireless communications system according to claim 1, wherein:

the first demodulation digital circuit includes:

15 a first complex filter for filtering, by using a digital filter, either one of a positive frequency component and a negative frequency component of the signal oversampled by the first sampler whose center frequency is closer to zero; and

a first received data reproducing section for reproducing
20 received data from the signal filtered by the first complex filter; and

the second demodulation digital circuit includes:

a second complex filter for filtering, by using a digital filter, either one of a positive frequency component and a negative
25 frequency component of the signal undersampled by the second

sampler whose center frequency is closer to zero; and

a second received data reproducing section for reproducing received data from the signal filtered by the second complex filter.

5

7. The wireless communications system according to claim 3, wherein:

the first demodulation digital circuit includes:

a first quadrature demodulator for
10 quadrature-demodulating the signal oversampled by the first sampler;

a first low-pass filter for low-pass-filtering the signal outputted from the first quadrature demodulator; and

a first received data reproducing section for reproducing
15 received data from the signal low-pass-filtered by the first low-pass filter;

the second demodulation digital circuit includes:

a second quadrature demodulator for
20 quadrature-demodulating the signal undersampled by the second sampler;

a second low-pass filter for low-pass-filtering the signal quadrature-demodulated by the second quadrature demodulator; and

a second received data reproducing section for
25 reproducing received data from the signal low-pass-filtered by

the second low-pass filter;

the first quadrature demodulator converts the signal oversampled by the first sampler to a signal including a component whose center frequency is zero; and

5 the second quadrature demodulator converts the signal undersampled by the second sampler to a signal including a component whose center frequency is zero.

8. The wireless communications system according to claim 7,
10 wherein the frequency f_j [Hz] is 3.000 [MHz].

9. A wireless digital receiver in a wireless communications system for transmitting/receiving a first wireless signal from a first wireless communications device and a second wireless signal
15 from a second wireless communications device, the first and second wireless signals having different frequency bands from each other, the wireless digital receiver receiving the second wireless signal in the first wireless communications device and digitally demodulating the second wireless signal, the wireless digital
20 receiver comprising:

a frequency converter for downconverting the second wireless signal transmitted from the second wireless communications device to a low-frequency signal whose center frequency is f_i [Hz];

a sampler for oversampling the low-frequency signal
25 downconverted by the frequency converter; and

a demodulation digital circuit for demodulating the signal oversampled by the sampler, wherein:

a sampling frequency used in the sampler and that used in the second wireless communications device are the same sampling
 5 frequency f_s [Hz];

the sampling frequency f_s [Hz] is set to a value that is an even-number multiple of a wireless symbol transmission rate such that oversampling is done in the sampler and undersampling is done in a sampler of the second wireless communications device;
 10 and

the center frequency f_i [Hz] of the low-frequency signal is $1/2$ to 1 times a frequency corresponding to a bandwidth of the first and second wireless signals and is $1/2^N$ (N is a natural number) times the sampling frequency f_s [Hz].
 15

10. The wireless digital receiver according to claim 9, wherein where the bandwidth of the first and second wireless signals is $2 \times B_{ch}$ [Hz] and the wireless symbol transmission rate is f_{sym} [Hz], the sampling frequency f_s [Hz] and the center frequency f_i [Hz] of the low-frequency signal are expressed as shown in the
 20 following expressions:

$$f_i = \frac{2k f_{sym}}{2^N}$$

$$f_s = 2^N f_i$$

where k is an integer satisfying

$$\frac{f_d + B_{ch}}{(n+1)f_{sym}} \leq k \leq \frac{f_d - B_{ch}}{nf_{sym}} \quad \dots \text{Exp. 12}$$

and

$$k \leq \frac{f_d}{2f_{sym}} \quad \dots \text{Exp. 14}$$

5 and N is an integer satisfying

$$\log_2 \left\{ \frac{f_d + B_{ch}}{(n+1)B_{ch}} \right\} \leq N \leq \log_2 \left\{ \frac{2(f_d - B_{ch})}{nB_{ch}} \right\} \quad \dots \text{Exp. 22}$$

where n is an integer satisfying

$$1 \leq n \leq \frac{f_d - B_{ch}}{2B_{ch}} \quad \dots \text{Exp. 7}$$

10 11. The wireless digital receiver according to claim 9,
wherein the center frequency f_i and the sampling frequency f_s are

$f_i = 3.072$ [MHz] and $f_s = 24.576$ [MHz],

$f_i = 3.072$ [MHz] and $f_s = 12.288$ [MHz],

$f_i = 4.608$ [MHz] and $f_s = 36.864$ [MHz],

15 $f_i = 4.096$ [MHz] and $f_s = 32.768$ [MHz], or

$f_i = 3.584$ [MHz] and $f_s = 28.672$ [MHz].

12. The wireless digital receiver according to claim 9,
wherein:

20 the demodulation digital circuit includes:

a quadrature demodulator for quadrature-demodulating the

signal oversampled by the sampler;

a low-pass filter for low-pass-filtering the signal quadrature-demodulated by the quadrature demodulator; and

a received data reproducing section for reproducing
5 received data from the signal low-pass-filtered by the low-pass filter; and

the quadrature demodulator converts the signal oversampled by the sampler to a signal including a component whose center frequency is zero.

10

13. The wireless digital receiver according to claim 9, wherein the demodulation digital circuit includes:

a complex filter for filtering, by using a digital filter, either one of a positive frequency component and a negative
15 frequency component of the signal oversampled by the sampler whose center frequency is closer to zero; and

a received data reproducing section for reproducing received data from the signal filtered by the complex filter.

20

14. A wireless digital receiver in a wireless communications system for transmitting/receiving a first wireless signal from a first wireless communications device and a second wireless signal from a second wireless communications device, the first and second wireless signals having different frequency bands from each other,
25 the wireless digital receiver receiving the first wireless signal

in the second wireless communications device and digitally demodulating the first wireless signal, the wireless digital receiver comprising:

a frequency converter for downconverting the first wireless
5 signal transmitted from the first wireless communications device to a low-frequency signal whose center frequency f_d [Hz] is equal to a difference between a center frequency of the first wireless signal and that of the second wireless signal;

a sampler for undersampling the low-frequency signal
10 downconverted by the frequency converter; and

a demodulation digital circuit for demodulating the signal undersampled by the sampler, wherein:

a sampling frequency used in the sampler and that used in the first wireless communications device are the same sampling
15 frequency f_s [Hz]; and

the sampling frequency f_s [Hz] is set to a value that is an even-number multiple of a wireless symbol transmission rate such that undersampling is done in the sampler and oversampling is done in a sampler of the first wireless communications device.
20

15. The wireless digital receiver according to claim 14, wherein where the bandwidth of the first and second wireless signals is $2 \times B_{ch}$ [Hz] and the wireless symbol transmission rate is f_{sym} [Hz], the sampling frequency f_s [Hz] is expressed as shown in the
25 following expression:

$$f_s = 2kf_{\text{sym}}$$

where k is an integer satisfying

$$\frac{f_d + B_{\text{ch}}}{(n+1)f_{\text{sym}}} \leq k \leq \frac{f_d - B_{\text{ch}}}{nf_{\text{sym}}} \quad \dots \text{Exp. 12}$$

and

$$k \leq \frac{f_d}{2f_{\text{sym}}} \quad \dots \text{Exp. 14}$$

5

where n is an integer satisfying

$$1 \leq n \leq \frac{f_d - B_{\text{ch}}}{2B_{\text{ch}}} \quad \dots \text{Exp. 7}$$

10 16. The wireless digital receiver according to claim 14,
wherein:

the center frequency f_d is 40.000 [MHz]; and

the sampling frequency f_s is 24.576 [MHz], 12.288 [MHz],
 $f_s = 36.864$ [MHz], $f_s = 32.768$ [MHz] or $f_s = 28.672$ [MHz].

15 17. The wireless digital receiver according to claim 14,
wherein:

the demodulation digital circuit includes:

a quadrature demodulator for quadrature-demodulating the
signal undersampled by the sampler; and

20 a low-pass filter for low-pass-filtering the signal
quadrature-demodulated by the quadrature demodulator; and

a received data reproducing section for reproducing

received data from the signal low-pass-filtered by the low-pass filter; and

the quadrature demodulator converts the signal undersampled by the sampler to a signal including a component whose center
5 frequency is zero.

18. The wireless digital receiver according to claim 14, wherein the demodulation digital circuit includes:

a complex filter for filtering, by using a digital filter,
10 either one of a positive frequency component and a negative frequency component of the signal undersampled by the sampler whose center frequency is closer to zero; and

a received data reproducing section for reproducing received data from the signal filtered by the complex filter.

15

19. A wireless digital receiver in a wireless communications system for transmitting/receiving a first wireless signal from a first wireless communications device and a second wireless signal from a second wireless communications device, the first and second
20 wireless signals having different frequency bands from each other, the wireless digital receiver receiving the second wireless signal in the first wireless communications device and digitally demodulating the second wireless signal, the wireless digital receiver comprising:

25 a frequency converter for downconverting the second wireless

signal transmitted from the second wireless communications device to a low-frequency signal whose center frequency is f_j [Hz];

a sampler for oversampling the low-frequency signal downconverted by the frequency converter; and

5 a demodulation digital circuit for demodulating the signal oversampled by the sampler after correcting a center frequency thereof to f_i [Hz], wherein:

a sampling frequency used in the sampler and that used in the second wireless communications device are the same sampling
10 frequency f_s [Hz];

the sampling frequency f_s [Hz] is set to a value that is an even-number multiple of a wireless symbol transmission rate such that oversampling is done in the sampler and undersampling is done in a sampler of the second wireless communications device;
15 and

the center frequency f_i [Hz] is $1/2$ to 1 times a frequency corresponding to a bandwidth of the first and second wireless signals and is $1/2^N$ (N is a natural number) times the sampling frequency f_s [Hz].
20

20. The wireless digital receiver according to claim 19, wherein where the bandwidth of the first and second wireless signals is $2 \times B_{ch}$ [Hz] and the wireless symbol transmission rate is f_{sym} [Hz], the sampling frequency f_s [Hz] and the frequency f_i [Hz] are expressed as shown in the following expressions:
25

$$f_i = \frac{2k f_{\text{sym}}}{2^N}$$

$$f_s = 2^N f_i$$

where k is an integer satisfying

$$\frac{f_d + B_{\text{ch}}}{(n+1)f_{\text{sym}}} \leq k \leq \frac{f_d - B_{\text{ch}}}{n f_{\text{sym}}} \quad \dots \text{Exp. 12}$$

5 and

$$k \leq \frac{f_d}{2f_{\text{sym}}} \quad \dots \text{Exp. 14}$$

and N is an integer satisfying

$$\log_2 \left\{ \frac{f_d + B_{\text{ch}}}{(n+1)B_{\text{ch}}} \right\} \leq N \leq \log_2 \left\{ \frac{2(f_d - B_{\text{ch}})}{n B_{\text{ch}}} \right\} \quad \dots \text{Exp. 22}$$

where n is an integer satisfying

$$1 \leq n \leq \frac{f_d - B_{\text{ch}}}{2B_{\text{ch}}} \quad \dots \text{Exp. 7}$$

10

21. The wireless digital receiver according to claim 19, wherein the demodulation digital circuit includes:

a quadrature demodulator for quadrature-demodulating the
15 signal oversampled by the sampler;

an automatic frequency controller for correcting the signal quadrature-demodulated by the quadrature demodulator to a signal having a component whose frequency is f_i [Hz];

a low-pass filter for low-pass-filtering the signal

frequency-corrected by the automatic frequency controller; and
a received data reproducing section for reproducing received
data from the signal low-pass-filtered by the low-pass filter.

5 22. The wireless digital receiver according to claim 19,
wherein the frequency f_j [Hz] is 3.000 [MHz].

23. An integrated circuit for use in a wireless digital
receiver in a wireless communications system for
10 transmitting/receiving a first wireless signal from a first
wireless communications device and a second wireless signal from
a second wireless communications device, the first and second
wireless signals having different frequency bands from each other,
the wireless digital receiver receiving the second wireless signal
15 in the first wireless communications device and digitally
demodulating the second wireless signal, the integrated circuit
comprising:

a frequency conversion section for downconverting the second
wireless signal transmitted from the second wireless
20 communications device to a low-frequency signal;

a sampling section for oversampling the low-frequency signal
downconverted by the frequency conversion section; and

a demodulation digital section for demodulating the signal
oversampled by the sampling section, wherein:

25 the signal demodulated by the demodulation digital

circuit has a center frequency of f_i [Hz];

a sampling frequency used in the sampling section and that used in the second wireless communications device are the same sampling frequency f_s [Hz];

5 the sampling frequency f_s [Hz] is set to a value that is an even-number multiple of a wireless symbol transmission rate such that oversampling is done in the sampling section and undersampling is done in a sampler of the second wireless communications device; and

10 the center frequency f_i [Hz] is $1/2$ to 1 times a frequency corresponding to a bandwidth of the first and second wireless signals and is $1/2^N$ (N is a natural number) times the sampling frequency f_s [Hz].

15 24. An integrated circuit for use in a wireless digital receiver in a wireless communications system for transmitting/receiving a first wireless signal from a first wireless communications device and a second wireless signal from a second wireless communications device, the first and second
20 wireless signals having different frequency bands from each other, the wireless digital receiver receiving the first wireless signal in the second wireless communications device and digitally demodulating the first wireless signal, the integrated circuit comprising:

25 a frequency conversion section for downconverting the first

wireless signal transmitted from the first wireless communications device to a low-frequency signal whose center frequency f_d [Hz] is equal to a difference between a center frequency of the first wireless signal and that of the second wireless signal;

5 a sampling section for undersampling the low-frequency signal downconverted by the frequency conversion section; and
a demodulation digital section for demodulating the signal undersampled by the sampling section, wherein:

10 a sampling frequency used in the sampling section and that used in the first wireless communications device are the same sampling frequency f_s [Hz]; and

15 the sampling frequency f_s [Hz] is set to a value that is an even-number multiple of a wireless symbol transmission rate such that undersampling is done in the sampler and oversampling is done in a sampler of the first wireless communications device.